Academia Journal of Environmental Sciences 2(1): 006-014, January 2014
DOI: http://dx.doi.org/10.15413/ajes.2013.0030
ISSN: 2315-778X

Academia Publishing

Research Paper

A review on reduction of greenhouse gas emission from ruminants through nutritional strategies

Shigdaf Mekuriaw[1, 2]*, Firew Tegegn[2] and Alemayehu Mengistu[3]

[1]Andassa Livestock Research Centre, P. O. Box 27, Bahir Dar, Ethiopia.
[2]Bahir Dar University, College of Agriculture and Environmental Sciences, P. O. Box 79, Bahir Dar, Ethiopia.
[3]Addis Ababa University, Faculty of Science, Biology Department P. O. Box Urael Branch, 62291, Addis Ababa, Ethiopia.

*Corresponding author. E-mail: shigdafmekuriaw@yahoo.com.

Accepted 11th October, 2013

ABSTRACT

Greenhouse gas mitigation has become a major topic of discussion at international, national and local levels, with strategies being developed to reduce emissions. The possibility of man-made releases of GHG's possibly contributing to climate change has been the key driver in the push to reduce greenhouse gas emissions, with many people, including prominent scientists and world leaders concerned about the potential changes to the environment. This concern about greenhouse gases has resulted in a variety of research targeted towards mitigating emissions from all sectors. Current research in some areas indicates that improving the production process by making it more efficient not only reduces greenhouse gas emissions but improves the economics because there is less waste products. The emission of greenhouse gases, notably of methane, by domestic animals and possible ways of reduction has been the subject of many international studies in recent years. Methane mitigation in ruminants is possible through various strategies. Today, the feeding management approach is the most developed. The sustainability of methane suppressing strategies is an important issue. This review has identified a number of feeding strategies that will result in reduced methane emissions from ruminants such as the feeding of highly digestible forages, concentrates, diet manipulation to provide alternate hydrogen acceptors, inclusion of legumes in forage mixtures, inclusion of supplemental fats in diets and diet manipulation to shift the fermentation pathway. From the review, we can conclude that it is important to adopt those strategies based on their potential on methane reduction as well as, environmentally friendly. The choice of application primarily depends on the cost associated with it.

Key words: Methane, ruminant, greenhouse gas, climate change, enteric fermentation.

INTRODUCTION

Climate change is the biggest global health threat of the 21st century. A systematic appraisal of available evidence showed that the risks from changing patterns of disease, food insecurity, unsafe water and sanitation, damage to human settlements, extreme events, and population growth and migration were far more severe for human health than most observers had understood.

The message added an important new dimension to the political debate about how to respond to climate change. The threat was not only environmental and economic; it was directed at life itself. Global demand for livestock products is expected to double during the first half of this century, as a result of the growing human population, and its growing affluence. Climate change is one of the most serious long-term challenges facing farmers and livestock owners around the globe today. These climate changes will greatly impact arable agriculture, especially forage and grazing livestock production, which are directly dependent

upon weather and climate (Alan, 2008).

The greenhouse effect is a natural phenomenon necessary for life on earth. Greenhouse gases are atmospheric gases that absorb and re-emit long-wave radiation released by the earth back to the surface and as a consequence average global temperatures are predicted to rise (0.5 to 2.5°C by 2030) (IPCC, 2001). After carbon dioxide, the most important greenhouse gas is methane which traps over 21 times more heat per molecule as compared to carbon dioxide CO_2 (EPA, 2003). One of the largest biogenic (that is, produced by a living organism) source of CH_4 is digestive fermentation from ruminant animals (Alan, 2008).

Microbial enteric fermentation in the gastrointestinal tract of livestock can produce CH_4 gas as a by- product. On average, about 4 to 12% of Gross Energy Intake (GEI) is converted to CH_4 gas. Ruminants with their large fore-stomach contribute the most per head per day (Karin, 2001). Several techniques to measure CH_4 losses from farm animals exist. They were recently reviewed by Kebreab et al. (2006b); most widely used among them are respiration calorimetric chambers and sulphur hexafluoride (SF_6) as a tracer gas. Also, there are several ways to express CH_4 losses; as % of GEI and liter per kg of dry matter intake (Giger-Reverdin et al., 2003).

According to EPA (2003), reducing methane emissions is one of the most cost-effective ways to realize immediate environmental benefits because of methane's potency as a greenhouse gas. Since methane represents a loss of carbon from the rumen and therefore an unproductive use of dietary energy, scientists have been looking for ways to suppress its production. A quarter of the greenhouse gases come from animals themselves, mainly from cows, sheep and goats, because of the bacteria in their stomach.

Therefore, feeding and grazing strategies to mitigate CH_4 emissions can contribute to reducing overall GHG emissions, as well as, improve cattle performance (Alan, 2008). The emission of greenhouse gases (GHG), notably of methane (CH_4), by domestic animals and possible ways of reduction has been the subject of many international studies in recent years (Moss et al., 2000; Boadi et al., 2004; Kebreab et al., 2006a) because mitigating methane losses from cattle has economic as well as environmental benefits. Therefore, the aim of this paper is to review the potential nutritional mitigation strategies to reduce methane production from ruminants.

PRINCIPLES AND BACKGROUND OF METHANE PRODUCTION

Sources of greenhouse gases from ruminant animals

There are three main sources of greenhouse gas emissions in agriculture: enteric fermentation, agricultural soils and manure management. Animal agriculture contributes to accumulation of methane gas directly through production of methane in fermentative digestion in the rumen.

Enteric fermentation (fermentation in the digestive tract) is a natural part of the digestion process which results from the activity of microorganisms in the digestive tract. Digestion in ruminants (for example, cattle and sheep) differs from that in monogastrics (for example, pigs and poultry) in that substantial fermentation occurs in their large stomach called the rumen, resulting in large quantities of CH_4 being produced which are voided through belching (Frank et al., 2000).

Methane production

Methane originates from anaerobic microbial fermentation processes in the gastro-intestinal tract of ruminant animals. This fermentation occurs particularly in the reticulorumen, rumen in short. In an adult cow, the rumen occupies a volume of over 100 L of which usually 85 to 90% is fluid (Moss et al., 2000). The high moisture content and a temperature that is kept rather constant at around 37°C makes this an eminently suited environment for microbes to survive and grow, provided the microbes are regularly supplied with a suitable substrate. Substrates needed by the microbes are provided through the ingestion of feed by the host animal. The feed ingested by a ruminant is attacked by the microbes and degraded in a wide range of end products.

The anaerobic condition in the rumen and hindgut limit the oxidation of organic substrate into carbon dioxide and water, but an internal rearrangement of the carbon, hydrogen and oxygen present in the feed between microbial biomass and the end products, keeps the system going. During this process, reducing equivalents (H_2) are generated.

To prevent the accumulation of H_2, which by itself is poisonous to the microbes, a H_2 sink is needed. Various H_2 sinks are present in the rumen of which the conversion of H_2 and CO_2 into CH_4 is by far the most important. An accumulation of CH_4 is prevented by eructation and respiration, and the CH_4 is emitted to the environment.

Other important end products of fermentation are microbial mass and volatile fatty acids. Methanogens co-exist with the substrate degrading micro-organisms and produce CH_4 from CO_2 and H_2. By far, the major part of the H_2 formed in the rumen is converted into CH_4 (Mills et al., 2001). Besides methanogenesis, H_2 and CO_2 can be converted to acetate by acetogens, which are also present in the rumen environment (Moss et al., 2000).

In addition to that in the rumen, fermentation also in the hindgut contributes to enteric CH_4 production. This contribution appears generally to be less than 10% and slightly lower than the contribution of the hindgut to the digestion of organic matter (Kebreab et al., 2006b). In Canada, CH_4 emissions from enteric fermentation are

estimated by multiplying the population of various animal types by average emission rates as presented in Table 1 (Environment Canada, 2002).

Factors influencing methane yield

Factors that can be identified as influencing CH_4 yield include dietary characteristics as well as, the fermentation conditions in the rumen. Important dietary characteristics are daily feed intake and the resulting rumen fill the proportion of concentrates in dietary dry matter, the composition, rate and extent of degradation of individual feed fractions (the types of carbohydrate and protein) in dietary dry matter.

Among important fermentation conditions are acidity of rumen fluid, the presence of unsaturated long chain fatty acids, composition of the microbial population within the rumen, dynamics of the passage of particles, fluid and the microbial population, inflow of saliva and the absorption capacity of the rumen wall. The combined effect of both types of factors is represented in conditions that characterize the ruminant, such as production level, stage of lactation and management related interventions like grazing regime, feeding regime, housing and milking (Smink et al., 2003).

Because of the multiple factors that may have changed simultaneously and have affected rumen fermentation and hence, CH_4 yield, the effect of nutritional measures on VFA and CH_4 production may be difficult to predict and interpret. The observed effect of a nutritional intervention on CH_4 yield is therefore strongly confounded with the concomitant changes brought about in these factors. Some of the principal factors affecting rumen function and CH_4 production are subsequently discussed.

Feed intake

Changes in dry matter intake not only affect the amount of substrate available for microbial degradation, but it also changes fermentation conditions and the size of the microbial population. For example, the fate of ingested starch changes with changes in the amount of dry matter ingested, as increased intake levels will lead to a proportionally higher amount of starch digested in the small intestine rather than being fermented in the rumen. Almost all models that predict CH_4 production by ruminants require daily feed intake or a closely related variable as an input.

Intrinsic degradation characteristics

Microbial degradation of substrates in the rumen depends primarily on intrinsic characteristics that determine the susceptibility of the substrate to be attacked, degraded and utilized by micro-organisms. Obviously, intrinsic characteristics are important determinants of substrate degradation and utilization by micro-organisms, VFA production and the concomitant CH_4 yield. A higher passage rate due to a higher feed intake level as well as, a less degradable substrate may both increase the escape of substrate and lead to a decrease in CH_4 yield.

Type of substrate fermented and type of diet

Different types of fermented carbohydrate give different profiles of VFA production and hence, CH_4 yield (Bannink et al., 2005a). Independent of the effect of fluid acidity, an analysis of VFA profiles showed about 25 and 15% lower CH_4 yields for fermented sugars and starch, respectively, on concentrate-rich diets as compared to forage-rich diets (Bannink and Dijkstra, 2005b).

Fermentation rate and fluid acidity

The acidity of rumen fluid influences rumen fermentation. As the pH values lower than 6.2 appear to reduce the activity of fibrolytic micro-organisms degrading cell walls, hence, pH determines cell wall degradability and its contribution to microbial growth, and VFA and CH_4 yields. An increased rate of substrate fermentation as a result of an increased feed intake or due to large concentrate meals, leads to increased rates of VFA production, higher VFA concentrations and a more acidic rumen fluid. As a result, the profile of VFA shifts towards a propionate lower CH_4 yield. In an analysis of *in vivo* data on rumen fermentation, a decrease of the pH of the rumen fluid from 6.5 to 5.5 was estimated to lead to about 15% less CH_4 produced from both fermented sugars and starch (Bannink et al., 2005a, b).

Nutritional strategies to reduce methane emission

In general, methane production by livestock represents inefficiency because the feed energy converted to methane is not used by the animal for maintenance, growth, production and reproduction. While efforts to improve efficiency by reducing methane formation in the rumen directly have been of limited success, it is recognized that improvements in overall production efficiency will reduce methane emissions per unit of product produced. Several mechanisms influence the availability of hydrogen in the rumen and subsequent production of enteric methane emissions by cattle. Processes that yield propionate act as net proton-using reactions while those that yield acetate result in a net increase in protons.

A number of experiments were carried out to investigate possible mitigation practices. Changes in feeding strategy

Table 1. Methane emission factors for domesticated livestock.

Animal types	Enteric fermentation (kg CH_4/head/year)
Bulls	75
Dairy cows	118
Beef cows	72
Dairy heifers	56
Beef heifers	56
Heifers for slaughter	47
Steers	47
Calves	47
Sheep	8 0
Goats	8 0
Horses	13

Source: Environment Canada (2002).

have a large impact on GHG production by farm animals.

It is widely recognized that alterations in the diet strongly affect rumen functioning and the performance of ruminants (for example, roughage: concentrate ratio, or the fiber, starch, sugars and protein content of the feed). Similarly, dietary composition may strongly affect the supply and subsequent fermentation of substrate in the large intestine of pigs as well as, ruminants (quantity of and type of starch, fibre and protein inflow to large intestine). These feeding strategies are subsequently discussed.

Forage utilization

Forage/pasture quality

Methane production in ruminants tends to decrease with the quality of the forage fed. A Manitoba study showed that CH_4 emissions of grazing steers that had access to high quality pastures declined by 50% as compared to emissions from matured pastures (Karin, 2001). Boadi and Wittenberg (2002) have demonstrated that forage quality has a significant impact on enteric methane emissions.

Efficiency of forage fermentation was linked to biomass availability and quality of pasture. Further, it appeared that emissions were influenced by pasture dry matter availability and quality, in that emissions were highest (11% of GEI) when pasture quality and availability were low. Emissions were lower when pasture quality was high. According to Ominski and Wittenberg (2006), steers grazing during the early period of the grazing season had 44 and 29% less energy lost as methane compared to steers grazing during the mid and late grazing periods, respectively. Further, steers experienced a 54% decline in enteric emissions upon entry verses exit of the grazing paddock.

This study has concluded that enteric CH4 emissions are highest when the animal is presented with poor-quality forage and has limited ability to select higher quality forage components as a consequence of reduced dry matter availability.

Boadi and Wittenberg (2002) reported that forage quality has a significant impact on enteric CH_4 emissions. Cattle given hay of high (61.5% *in vitro* organic matter digestibility [IVOMD]), medium (50.7% IVOMD) and low (38.5% IVOMD) qualities had significantly higher dry matter intake and lower enteric CH_4 emissions as forage quality increased.

In another study, the authors observed the same phenomenon on pasture (Boadi and Wittenberg, 2002). It can be concluded that enteric CH_4 emissions are highest when the animal is presented with poor-quality forage and has limited ability to select higher quality forage components as a consequence of reduced dry matter availability (Ominski and Wittenberg, 2006). In cattle on poor quality forage, a number of essential microbial nutrients may be deficient and microbial growth efficiency in the rumen is low. In these conditions, methane produced may represent 15 to 18% of the digestible energy (Leng, 2009).

It can be concluded that enteric emissions are highest when the animal is presented with poor quality forage and has limited opportunity to select higher quality forage as a consequence of reduced dry matter availability.

Forage species (legume versus grass)

McCaughey et al. (1999) have demonstrated that the species present in a pasture may significantly influence enteric methane emissions. Pasture types examined were alfalfa-grass mix (78% alfalfa and 22% meadow bromegrass) or 100% meadow brome grass; cows grazing the alfalfa-grass pastures had significantly greater dry matter intake; lower methane production was observed as compared to their counterparts grazing grass-only pastures. Inclusion of legume-based forages in the diet is

associated with higher digestibility and faster rate of passage resulting in a shift toward high propionate in the rumen and reduced methane production.

Use of legumes in grazing rotations as observed by McCaughey et al. (1999) lower CH_4 emissions (7.1% of GEI) from alfalfa-grass pasture than grass only pastures (9.5% of GEI). Methane yield from the ruminal fermentation of legume and legume-grass forages are also generally lower than the yield from grass forages (Moss et al., 2000). Explanation for the reduced CH_4 emissions can be attributed to the lower proportion of structural carbohydrates in legumes and faster rate of passage which shift the fermentation pattern towards higher propionate production (Alan, 2008). Research from New Zealand (Ramirez-Restropoa and Barry, 2005) suggests that feeding forage legumes like lucerne or red clover also tends to decrease CH_4 losses as compared to grass.

Pasture/grazing management

Several Canadian research studies have examined the impact that pasture and grazing management has on enteric CH_4 emissions. A study by McCaughey et al. (1997) reported that CH_4 production was greatest for steers continuously grazing at low stocking rates (1.1 steer per hectare with 307 L per day) and least for steers grazing continuously at high stocking rates (2.2 steers per hectare with 242 L per day).

A possible explanation for these observed results for the higher stocking rate may be due to lower forage availability and intake for the grazing animal. When pastures were rotationally grazed, stocking rates had no effect on CH_4 production. At low stocking rates, CH_4 production was 9% lower on rotational grazing than continuous grazing. Pasture quality is the critical factor in ensuring lower CH_4 emissions from grazing animals in any particular grazing system (Alan, 2008).

Forage preservation and processing

Forage preservation method (hay versus silage)

Shingfield et al. (2002) reported that the intensity of ruminal fermentation was quantitatively influenced by the method of preservation of alfalfa; total and individual VFA productions were lower with alfalfa silage compared to alfalfa hay. Total methane production was depressed (33%) by the utilization of alfalfa silage instead of alfalfa hay. Fractions of GE intake and DE lost as methane were also lower (32 and 28%, respectively) with alfalfa silage than with alfalfa hay.

The same author explains that the highest CH_4 losses reported in the literature is associated with feeding ryegrass silage and lotus silage. This would not be unexpected since digestion is reduced in the rumen with ensiled forages due to the extensive fermentation that occurs during silage making. Often, silage additives such as bacterial inoculants and organic acids are added to the ensiling process to enhance the quality and palatability. These ensiling additives can lower acetic acid and increase propionate production and thereby reducing enteric CH_4 emissions.

Processing of forage

The physical form of feed (particularly roughages) is another factor which influences the extent of methanogenesis: a whole pelleted diet tends to reduce CH_4 production. Grinding of forages to improve the utilization by ruminants has been shown to decrease CH_4 losses per unit of feed intake by 20 to 40% when fed at high intakes (Johnson et al., 1996).

The explanation for the decline in CH_4 production is due to the lower fibre digestibility, decreased ruminally available organic matter and faster rate of passage associated with ground or pelleted forages (LeLiboux and Peyraud, 1999). The main limitation to the potential use of more processed forage feed to reduce CH_4 emission is the economical cost to cattle producers.

Formation of end-products of fermentation in the rumen was also affected by processing of hay: pelleting alfalfa hay decreased VFA production. Methane production was reduced (20%) by the physical treatment of hay. Similarly, methane losses reported as 21 and 13% respectively of GE intake and DE were depressed by processing of alfalfa hay (Alan, 2008).

Forage maturity

It is recognized that CH_4 production in ruminants generally increases with forage maturity (Moss et al., 2000). In contrast, a study by Pinares-Patino et al. (2003) evaluated beef cows grazing on a non-specific pasture of timothy at four stages of maturity: early vegetative, heading, flowering and senescence observed organic matter intake and CH_4 emissions lower only at heading.

The effect of forage maturity on methane production was evaluated using a diet based on 100% alfalfa hay harvested at two different stages of maturity: vegetative and mid-bloom. The replacement of the mid-bloom alfalfa hay with the vegetative hay had a small effect (4%) on methane production. Boadi et al. (2002) observed early grazing of alfalfa-grass pastures reduced CH_4 production by 29 to 45% in steers as compared to grazing at mid and late seasons.

Concentrates

Compared to forages, concentrates are usually lower in cell wall components. Due to the presence of non-structural carbohydrates (starch and sugars), concentrates normally

ferment faster than forages, giving rise to elevated levels of propionic acid. Veen (2000) suggest that CH_4 production can be lowered by almost 40% (from 272 to 170 g/day) when a forage rich diet is replaced by a concentrate rich diet. Increasing the dietary proportion of concentrates usually reduces CH_4 losses. The CH_4 reduction observed by Bannink et al. (1997) showed that concentrate rich diets have lower and higher coefficients of conversion of substrate into acetate and propionate respectively.

Concentrates and concentrate ingredients are quite variable with regard to their content of structural (cellulose, hemicelluloses) and non-structural (starch, sugars) carbohydrates. The degradative behaviour of both groups of carbohydrates also varies widely, notably the rate of degradation of starch. Consequently, VFA profile and CH_4 loss vary accordingly. All carbohydrate fractions yielded CH_4, but the highest contribution to CH_4 losses came from sugars. The low proportion of GEI lost as CH_4 was probably caused by a propionate type of rumen fermentation, the very low figure for the corn based diet must have resulted from a larger proportion of starch in corn escaping digestion in the rumen. Feeding more concentrates per animal, especially those with a higher amount of (rumen resistant) starch and less sugars has a very positive effect on the reduction of CH_4 losses (Tamminga et al., 2007).

Addition of fats and oil to ruminant diets

There are a number of mechanisms that can affect the rumen fermentation process within the animal that subsequently will reduce enteric CH_4 emissions. A number of recent reviews on this subject (Boadi et al., 2004; Ominski and Wittenberg, 2006) are available that evaluate the pros and cons of the addition of fats to cattle diets, ionophores, defunation, bacteriocins, probiotics, and use of alternative hydrogen acceptors or sinks (that is, organic acids: malate and fumarate etc) to mitigate CH_4 emissions.

It is known that there is a reduction in the amount of feed fermented with additions of fats. Methane emission was reduced by 33% when 4% canola oil was added to a diet containing 85% concentrate in a feedlot study (Karin, 2001). Adding oils to dairy diets has also been recommended as a way to reduce CH_4 losses.

According to Veen (2000), possibilities to include more fat in dairy diets is limited, because feeding fat of animal origin is forbidden and many vegetable fats often do stimulate milk production, but have a negative influence on fat and protein content of the milk. According to this author, attention should be paid to the use of fish oils, because there are indications that they might reduce CH_4 emission without showing a negative effect on cell wall digestibility in the rumen.

In beef cattle, the addition of sunflower oil (400 g per day) decreased CH_4 emissions by 22% with no negative effect on DM intake, but reductions in DM and NDF digestibility were 9 and 23% respectively (McGinn et al., 2004). Currently, oil prices are rising because of the increasing demands for oil by booming economies in Asia and political instability of oil producing regions. High oil prices reduce the chances of vegetable fats and oils as a cost-effective measure to reduce CH_4 losses.

Among the feeding factors able to reduce CH_4 emission by ruminants, particularly cattle, fat-rich feeds have a certain interest, presumably more for their high net energy content than for their ability to reduce methanogenesis. Results of adding fats to diets of cattle on CH_4 emission are variable and seem to be influenced by the type of FA (chain length, degree of unsaturation), the type of animal (beef versus dairy cattle), the type of diet (forage versus concentrate rich), and the length of the experimental period. Next to reduced CH_4 losses, reductions in DMI and cell wall digestibility have often been observed (Tamminga et al., 2007).

Feeding additives

Several bioactive compounds among which were essential oils, ionophores, saponin containing plant extracts, surfactants and tannins were investigated *in vitro* for their protozoa reducing activity (Hristov et al., 2003). Ionophores, notably monensin, have been suggested as depressing agents for CH_4 production in ruminants and were discussed by Moss et al. (2000).

Organic acids

A number of feed additives have shown potential as inhibitors of CH_4 *in vitro* experiments (Tamminga et al., 2007). A number of recent reviews on this subject (Boadi et al., 2004; Ominski and Wittenberg, 2006) are available that evaluate the addition of organic acids (malate and fumarate etc) to cattle diets and use of alternative hydrogen acceptors or sinks to mitigate CH_4 emissions.

Organic acids (malate, fumarate) have been assayed as diet additives. *In vivo* results are inconsistent. An exceptional decrease in methane production by 75% has been shown by Wallace et al. (2006) with 10% encapsulated fumaric acid in the diet of sheep, but the hydrogen used to produce propionate from fumarate is not enough to explain such a drop in methane. Further research is needed with such a product (Martin et al., 2009).

It has also been suggested that the addition of organic acids and the intermediates of carbohydrate degradation in the rumen would stimulate the production of propionic acid in the rumen and could reduce CH_4 losses (Castillo et al., 2004), by acting as a H_2 sink. Newbold et al. (2005) tested 15 potential precursors of propionate, including pyruvate, lactate, fumarate, acrylate, malate and citrate in short-term batch cultures.

Sodium acrylate and sodium fumarate produced the most consistent effect decreasing CH_4 production by between 8 and 17%. Free acids rather than salts were more effective in reducing CH_4, but also decreased pH with possible negative effects on fibre degradation. In longer term (21 days) *in vitro* incubations and fumarate addition decreased CH_4 production by 28% whilst maintaining DM degradation, whereas malate was not effective.

Ionophores

Some feed additives, such as the ionophores, reduce CH_4 production after their inclusion in the diet. Ionophores are frequently utilized in beef cattle production systems to improve animal performance, as well as, to reduce the incidence of bloat and prevent outbreaks of coccidiosis. Although, ionophore supplementation may reduce methane emissions by 20 to 25%, work conducted at the University of Colorado has demonstrated that an adaptive response occurs in both forage and grain diets, resulting in a return to baseline methane levels in approximately two weeks (Johnson et al., 1996).

Plant secondary metabolites

To protect themselves against microbial and insect attack, plants produce a variety of secondary compounds. Some of them are also toxic to animals, but others are not. Research on the effect of plant secondary metabolites, notably condensed tannins (Ramirez-Restropo and Barry, 2005), essential oils and saponins (Wallace, 2004), is receiving much attention these days, primarily with the aim that secondary plant metabolites can possibly replace antimicrobials.

As a side effect, in some instances inhibiting effects on CH_4 have been observed, most likely mediated through an effect on rumen protozoa. In recent years, there is growing interest in the use of plant secondary compounds (tannins and saponins) as a CH_4 mitigation strategy because of their natural origin in opposition to chemical additives. Most trials with plant extracts have been done *in vitro* and the response of these molecules on methanogenesis is highly variable.

Condensed tannins

A number of plant secondary metabolites have shown some potential as inhibitors of CH_4 *in vitro* experiments. This seems notably the case with condensed tannins that reduced CH_4 losses both *in vitro* and *in vivo* experiments (Tamminga et al., 2007). In New Zealand sheep, housed indoors and fed with different forages (lucerne, sulla, red clover, cichory and lotus), CH_4 losses were reduced by between 20 and 55% as compared to animals pastured on ryegrass/white clover mixtures (Ramirez-Restropo and Barry, 2005). In goats fed with the condensed tannin containing forage sericea lespedeza, Puchala et al. (2005) observed in Oklahoma (USA) a reduction in CH_4 loss of over 30%.

Saponins

Saponins are naturally occurring surface-active glycosides, occurring in many plant species, wild plants as well as, cultivated crops. They usually consist of a sugar moiety linked to a hydrophobic compound, either triterpenoid or steroid in nature (Francis et al., 2002). Saponin containing plants and their extracts has been shown to suppress the bacteriolytic activity of rumen ciliate protozoa (Moss et al., 2000). Saponins are considered to have detrimental effects on protozoa through their binding with sterols present on the protozoal surface (Francis et al., 2002). Because of their anti protozoal activity, saponins might have the potential to reduce CH_4.

Supplementation of molasses block

Research in the past 20 years has clearly illustrated that supplementation of cattle on low quality forage based diets increases productivity through increasing efficiency of feed utilization (Leng, 1990). A mixture of nutrients as can be supplied for instance in molasses urea multi-nutrient block lick ensures an efficient microbial digestion in the rumen. A small amount of protein meal that is directly available to the animal (that is, by-pass protein) stimulates both productivity and efficiency of feed utilization (the evidence and theory is discussed.

Provision of molasses urea blocks to draught oxen which in general receive only straw in most developing countries will have a major effect on methane production, reducing it to perhaps half the present production rate (Leng, 2009).

CONCLUSION

Methane mitigation in ruminants is possible through various strategies. Today, the feeding management approach is the most developed. Strategies are proposed to reduce methanogenesis in ruminants. Their complete evaluation should include consequences on animal performances, safety for the ruminant and the consumer, and economical viability. Environmental impacts of such strategies should also take into consideration a global vision of production systems that considers all greenhouse gases emissions from the animal up to the farm scale as well as, grassland use.

Research conducted to date has demonstrated there are

different nutritional strategies to reduce methane emissions from ruminant animals. These methods include: improving the quality of forage, improving grazing practices, use of rotational grazing instead of continuous grazing, inclusion of legumes in legume forage mixes, feeding highly digestible forages, processing and preservation of feeds and adding fat and oils. The choice of application of the potential mitigation strategies and adoption into the industry will primarily depend on the cost associated with it. Strategies that are cost effective and have no potential negative effects on livestock production hold a greater promise.

RECOMMENDATION

In order to reduce the methane emission those feeding strategies, land use change for grazing and land degradation (Alemayehu, 2008) should be getting focus through integrated research and extension approach.

REFERENCES

Alan I (2008). Strategies to Reduce Greenhouse Gas Emissions through feeding and Grazing management. Swift Current Research Centre EMBO Rep. 9(6):508–511.

Alemayehu M (2008). Feature Article: Climate variability and change. Eth. J. Anim. Pro. 8(1):94-98.

Bannink A, De Visser H, Klop A, Dijkstra J, France J (1997). Impact of diet specific input parameters on simulated rumen function. J. Theoret. Biol. 184:371-384.

Bannink A, Dijkstra J, Mills JAN, Kebreab E, France J (2005a). Nutritional strategies to reduce enteric methane formation in dairy cows. In: Emissions from European Agriculture, pp.367-376 [T. Kuczynski, U. Dämmgen, J. Webb and A. Myczko, editors]. Wageningen Academic Publishers, Wageningen, the Netherlands.

Bannink A, Dijkstra J, Mills JAN, Kebreab E, France J (2005b). A dynamic approach for evaluating farm-specific as well as general policies to mitigate methane emissions by dairy cows. Proc. 4th Int. Symp. non-CO 2 Greenhouse Gases (NCGG-4). Science, Control, Policy & Implementation. A. Van Amstel, Coordinator. Millpress (www.millpress.nl), Utrecht, NL

Boadi D, Wittenberg KM (2002). Methane production from dairy and beef heifers Fed forages differing in nutrient density using the sulphur hexafluoride (SF6) tracer gas technique. Can. J. Anim. Sci. 82:201.

Boadi D, Wittenberg KM, McCaughey WP (2002). Effects of grain supplementation on methane production of grazing steers using the sulphur hexa fluoride (SF6) tracer gas technique. Can. J. Anim. Sci. 82:151-157.

Boadi D, Benchaar C, Chiquette J, Massé D (2004). Mitigation strategies to reduce enteric methane emissions from dairy cows. Update review. Can. J. Anim. Sci. 84:319-335.

Castillo C, Benedito JL, Méndez J, Pereira V, López-Alonso M, Miranda M, Hernández J (2004). Organic acids as a substitute for monensin in diets for beef cattle. Anim Fd. Sci. Technol. 115:101-116.

Environment Canada (2002). Canada's Greenhouse Gas Inventory 1990-2000 Greenhouse Gas Division Environment Canada. http://www.ec.gc.ca/pdb/ghg/1990_00_report/acknow_e.cfm

EPA (Environmental Protection Agency) (2003). Global Warming-Emissions. U.S. Environmental Protection Agency.

Francis G, Kerem Z, Makkar HSP, Becker K (2002). The biological action of saponins in animal systems: a review. Br. J. Nutr. 88:687-605.

Frank O, Michael R, John C, Pat T, Owen C, Lenehan JJ, Dan L, Bernard H, Eddie J, Michael H (2000). CLIMATE CHANGE – Estimation of Emissions of Greenhouse Gases from Agriculture and Strategies for their Reduction (2000-LS-5.1.1) Synthesis Report. UCD School of Agriculture, Food Science and Veterinary Medicine Teagasc, Johnstown Castle Research Centre, Co. Wexford, Ireland.

Giger-Reverdin S, Morand-Fehr P, Tran G (2003). Literature survey of the influence of dietary fat composition on methane production in dairy cattle. Livest. Prod. Sci. 82:73-79.

Hristov AN, Ivan M, Neill L, McAllister TA (2003). Evaluation of several potential bioactive agents for reducing protozoal activity in vitro. Anim. Fd. Sci. Technol. 105:163-184.

IPCC (2001). In: Houghton JT (Eds.), Climate Change 2001: The Scientific Background, vol. 94. Cambridge University Press, Cambridge, UK.

Johnson DE, Ward GM, Ramsey JJ (1996). Livestock methane: current emissions and mitigation potential, in Nutrient Management of Food Animals, CRC Press Inc., New York, chapter 15.

Karin W (2001). GHG emissions from Agriculture in Manitoba. Boadi Research Associate, Department of Animal Science University of Manitoba, Winnipeg, Manitoba R3T 2N2, *May 11 2001.* http://www.iisd.org/taskforce/pdf/dept_animal_sci.pdf

Kebreab E, France J, McBride BW, Bannink A, Mills JAN, Dijkstra J (2006a). Evaluation of models to predict methane emissions from enteric fermentation in North American Cattle. In: Modelling Nutrient Utilization in Farm Animals, Eds, E. Kebreab, J. Dijkstra, J. France, A. Bannink & W.J.J. Gerrits,. CAB International, Wallingford, UK.

Kebreab E, Clark K, Wagner-Riddle C, France J (2006b). Methane and nitrous oxide emissions from Canadian agriculture. A review. Can. J. Anim. Sci. 86:135-158.

LeLiboux S, Peyraud JL (1999). Effect of forage particle size and feeding frequency on fermentation patterns and sites and extent of digestion in dairy cows fed mixed diets. Anim. Feed Sci. Technol. 76:297-319.

Leng RA (1990). Contribution of methane from ruminants to global methane production and some strategies for reducing emission from ruminants. In 'Rural Industries: Workshop on Climate Change'. pp.31-40.

Leng RA (2009). Quantitative ruminant nutrition - A green science. Australian J. Agric. Res. 44:363-80.

Martin C, Doreau M, Morgavi DP (2009). Methane mitigation in ruminants: from Rumen microbes to the animal. Herbivores Research Unit, Research Centre of Clermont-Ferrand-Theix, Champanelle, France.

McCaughey WP, Wittenberg KM, Corrigan D (1997). Methane production by steers on pasture, Can. J. Anim. Sci. 77:519.

McCaughey WP, Wittenberg K, Corrigan D (1999). Impact of pasture type on Methane production by lactating beef cows, Can. J. Anim. Sci. 79:221.

McGinn SM, Beauchemin KA, Coates T, Colombatto D (2004). Methane emissions from beef cattle: Effects of monensin, sunflower oil, enzymes, yeast and fumaric acid, J. Anim. Sci. 82:3346-3356.

Mills JAN, Dijkstra J, Bannink A, Cammell SB, Kebreab E, France J (2001). A mechanistic model of whole-tract digestion and methanogenesis in the lactating dairy cow: Model development, evaluation, and application. J. Anim. Sci., 79, 1584-1597.

Moss AR, Jouany JP, Newbold J (2000). Methane production by ruminants: its contribution to global warming. Ann. Zootech. 49:231-253.

Newbold CJ, Lopez S, Nelson N, Ouda JO, Wallace RJ, Moss AR (2005). Propionate precursors and other metabolic intermediates as possible alternative electron acceptors to methanogenesis in ruminal fermentation in vitro. Brit. J. Nutr. 94: 27-35.

Ominski KH, Wittenberg KM (2006). Strategies for reducing enteric methane emissions in forage-based beef production systems. Pg. 261-272, in J.S. Bhatti, R. Lal, M.J. Apps, and M.A. Price eds., Climate Change and Managed Ecosystems. CRC Press Taylor & Francis Group.

Pinares-Patiño CS, Baumont R, Martin C (2003a). Methane emissions by charolais cows grazing a monospecific pasture of timothy at four stages of maturity. Can. J. Anim Sci. 83:769-777.

Puchala R, Min BR, Goetsch AL, Sahlu T (2005). The effect of a condensed tannin-containing forage on methane emission by goats. J. Anim. Sci. 83:182-186.

Ramirez-Restrepo CA, Barry TN (2005). Alternative temperate forages containing compounds for improving sustainable productivity in grazing ruminants. Anim. Fd. Sci. Technol. 120:179-201.

Shingfield KJ, Jaakkola S, Huhtanen P (2002). Effect of forage conservation method, concentrate level and propylene glycol on diet digestibility,

rumen fermentation, blood metabolite concentrations and nutrient utilization of dairy cows. Anim. Feed Sci. Technol. 97:1-21.

Smink W, Bos KD, Fitie AF, Van der Kolk LJ, Rijm WKJ, Roelofs G, Van den Broek GAM (2003). Methaanreductie melkvee. Een onderzoeksrapport naar inschatting van de methaanproductie vanuit de voeding en naar de reductiemogelijkheden via de voeding van melkkoeien. FIS report, Wageningen.

Tamminga S, Bannink A, Dijkstra J, Zom R (2007). Feeding strategies to reduce methane loss in cattle. Report 34. Wageningen University, Group Animal Nutrition Wageningen UR, Lelystad.

Veen WAG (2000). Veevoedermaatregelen ter vermindering van methaanproductie door herkauwers. Schothorst Feed Research proefverslag. www.robklimaat.nl

Wallace RJ (2004). Antimicrobial properties of plant secondary metabolites. Proc. Nutr. Soc. 63:621-629.

Wallace RJ, Wood TA, Rowe A, Price J, Yanez DR, Williams SP, Newbold CJ (2006). Encapsulated fumaric acid a means of decreasing ruminal methane emissions. Int. Congr. Ser. 1293:148–151.

Cite this article as:

Mekuriaw S, Tegegn F, Mengistu A (2014). A review on reduction of greenhouse gas emission from ruminants through nutritional strategies. Acad. J. Environ. Sci. 2(1): 006-014.

Submit your manuscript at:
www.academiapublishing.org/journals/ajes